[0030] An image apparatus according to some example embodiments of the inventive concepts may include a lens configured to focus incident light onto one or more image sensors of the image apparatus. The image apparatus may be configured to correct a calculated focal length of the lens according to a temperature of the lens or ambient temperature around the lens and calculate a depth of an object, relative to the image apparatus, using a phase-detection autofocus (AF) and the corrected focal length to improve accuracy of the depth. A temperature sensor may be disposed inside the image sensor to measure the temperature.

[0031] A typical camera lens may perform a function to concentrate light of an object and model the concentrated light with a lens equation. The lens equation may be expressed as Equation (1) below:

$$\frac{1}{f} = \frac{1}{s1} + \frac{1}{s2} \qquad \text{Equation (1)}$$

[0032] wherein s1 represents a distance between the object and the lens, s2 represents a distance between the lens and a focus, and f represents focal length.

[0033] Assuming that s1 is infinite, s2 may be approximated to f.

[0034] FIG. **1** illustrates a focal length difference depending on temperature when a distance s1 between the object and a lens is infinite, according to some example embodiments of the inventive concepts. FIG. **1** illustrates a focus F of light from an object **40** that is refracted through lens **30** at a first local temperature value T1 and a second local temperature value T2. Referring to FIG. **1**, assuming that s1 is infinite, the focal length "f" may vary depending on local temperature values associated with the lens **30**. As shown in FIG. **1**, the focal length f may vary based on whether a local temperature associated with the lens **30** is a first local temperature value T1 or a second local temperature value T2 (T2>T1). The focal length f of the lens **30** at the second local temperature value T2 may be greater than the focal length f of the lens **30** at the first local temperature value T1 by Δf.

[0035] FIG. **2**A and FIG. **2**B illustrate image apparatuses according to some example embodiments of the inventive concepts.

[0036] Referring to FIG. **2**A, an image apparatus **1** may include an image pixel **10** and a lens **30**. The image pixel **10** may be referred to as an image sensor **10**. In the example embodiments illustrated in FIG. **2**A, the image sensor **10** may be a two-phase detection (2PD) sensor. The image pixel **10** may include a right sensor **11** (also referred to as a right pupil sensor **11**) configured to capture an image of the object through a right lens pupil **31**R (a right image) and a left sensor **12** (also referred to as a left pupil sensor **12**) configured to capture an image of the object through a left lens pupil **31**L (a left image). When focuses of left and right images of the object captured by the right pupil sensor **11** and the left pupil sensor **12** do not match each other, the images are associated with a binocular disparity of the object at different positions in a sensor space.

[0037] Referring to FIG. **2**B, an image apparatus **1** may include an image pixel **10** and a lens **30**. In the example embodiments illustrated in FIG. **2**A, the image sensor **10** may be a metal shield pixel sensor. The image sensor **10** may include a right sensor **13** (also referred to as a right pupil sensor **11**) configured to capture an image of the object through a right lens pupil **31**R (a right image) and a left sensor **14** (also referred to as a left pupil sensor **12**) configured to capture an image of the object through a left lens pupil **31**L (a left image). The right sensor **13** may be a metal shield sensor that includes metal shield **15**R. The left sensor **14** may be a metal shield sensor that includes metal shield **15**L. When focuses of left and right images of the object captured by the right pupil sensor **13** and the left pupil sensor **14** do not match each other, the images are associated with a binocular disparity of the object at different positions in a sensor space.

[0038] FIG. **2**C illustrates a focal length variation and a disparity difference depending on temperature in an image sensor. In FIG. **2**C, an image pixel **10** may include a right portion **20**R and a left portion **20**L. In some example embodiments, the right portion **20**R may be one of right sensor **11** or right sensor **13**. In some example embodiments the left portion **20**L may be one of left sensor **12** or left sensor **14**.

[0039] Referring to FIG. **2**C, if and/or when a local temperature value associated with lens **30** is the first local temperature value T1, f_{T1} represents a first focal length of lens **30** and d_{T1} represents a first binocular disparity of left and right images of object **40** captured by the left and right portions **20**L and **20**R of the image sensor **10**. If and/or when a local temperature value associated with lens **30** is the second local temperature value T2, and where the second local temperature value T2 is greater than the first local temperature value T1, f_{T2} represents a second focal length of lens **30** and d_{T2} represents a second binocular disparity of left and right images of object **40** captured by the left and right portions **20**L and **20**R of the image sensor **10**. The second focal length f_{T1} may be greater than the first focal length f_{T1} by a variation value Δf, and the second disparity d_{T2} may be made greater than the first disparity d_{T1} by Δd.

[0040] In FIGS. **1** to **2**A, **2**B, and **2**C, the focal length or the binocular disparity may increase as a local temperature value associated with lens **30** increases. However, this is merely exemplary for description of inventive concepts and it should not be understood that increase in lens temperature surely leads to increase in the focal length or the binocular disparity.

[0041] FIG. **3** is a block diagram illustrating a method to calculate a focal length variation of depending on temperature associated with an image sensor **10** according to some example embodiments of the inventive concepts. The image sensor **10** may be a two-phase detection (2PD) sensor. A temperature associated with an image sensor **10** may include a local temperature value associated with a lens **30** in a common image apparatus **1** as the image sensor, where the lens **30** is configured to direct incident light onto at least a portion of the image sensor. The method may be implemented by an image apparatus **1** in which the image sensor **10** is included. A method for calculating the focal length variation of the image sensor **10** will now be described below with reference to FIG. **3**.

[0042] A left image and a right image may be sensed ("captured") by a left pupil sensor and a right pupil sensor of the image sensor **10**, respectively. The left image and the right image may include associated image data. Image data associated with an image may include pixel values of the image, including one or more of pixel color values, pixel depth values, some combination thereof, or the like.